International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 1695-1700

FINITE ELEMENT APPROACH OF FACE END MILLING CUTTER "EXPECTED TOOL LIFE ESTIMATION"

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ABSTRACT

Milling is highly used in manufacturing processes for the production of parts with required dimensions and shape. In an analysis of milling cutter the most important parameter is stress formation. Stress made along the finished edges and surfaces in milling activity have gigantic impact at surface quality and conduct of the finished parts and structures. Before the manufacturing, numerical analysis is performed to estimate the life of the tool by determining the stresses. In this present work, Finite Element (FE) Approach is used for designing accurately end mill cutting tools for milling of Titanium alloys by considering the stresses and forces developed on cutting tool. Design optimality of the end mill cutters of different sizes have been done by considering the tool forces to the minimum value. The three dimensional CAD models of the face end mill are created and Finite Element Analysis carried out by conforming the cutting tool forces for milling operation. By considering the titanium alloy as work piece material, the cutting tool forces, thermal variation of the cutting tool with the different geometry, tool wear, and stresses are simulated. This study leads to the development of optimal milling cutter design in order to achieve better tool life and quality of machined surface.

KEYWORDS: Face End Mill Cutter, Titanium (Ti6Al4V), FE Approach & Von-Mises/Equivalent Stress

Received: May 02, 2019; **Accepted**: May 23, 2019; **Published**: Jun 12, 2019; **Paper Id**.: IJMPERDJUN2019180

Original Article

INTRODUCTION

FINITE ELEMENT MODELLING

In this analysis the modelling software package used is ANSYS 19.2 for simulating machining processes. Linear static analysis is carried out to estimate the elastic Von-Mises stresses and strains of the cutter and workpiece and the nonlinear analysis is computed to estimate the material behaviors which undergoes high strain rate and higher amount of plastic deformation. The cutting performance is considered to be a critical parameter in any machine tool design. For various CAD software the numerical model accuracy can be maintained by the code supports tool geometry import. A solid geometrical model developed and directly imported into the ANSYS 19.2 and then discretization is carried out by meshing for the finite element analysis.

The Titanium (Ti6Al4V) is widely using material in current applications in aerospace, automotive and bio-medical firms because of its various properties, like low young's modulus, low thermal conductivity and its ability to sustain fluctuating loads at elevated temperatures. Even though this material has several applications in heavy engineering domains like aerospace, biomedical and automobile, machining of this material is complicated because the titanium alloy possesses higher hardness and high strength value at elevated temperatures.

Rapid tool wear and deteriorated machined surface are the common issues found due to the elevated temperature at the tool chip interface during machining of difficult to machine materials. The case of rapid tool wear for work material is more critical because of its lower thermal conductivity, as more than 80% of the heat developed at the cutting interface is absorbed by the cutting tool. By a general approach like use of cutting fluids such problems can be eliminated. Even after, the distortion in the finished material surface can be high lighted easily in the process of high speed machining. An attempt has been made by several researchers to trouble shoot this problem using different optimization techniques to manage the process variables and by using different cutting fluids. Some of the researchers recommended the use of high hardness cutting tool materials which will decrease heat affected zones; and improve the quality of work piece, the tool life and production rate. The problem is noticed repeatedly even after these attempts in many cases and this investigation tries to overcome this problem by adopting a technique of developing an optimally suitable end mill tool which leads to less cutting forces, thereby enhancing the machining surface quality and increase in tool life. The percentage composition and material property of titanium alloy (Ti6Al4V) are as listed in Table 1 and Table 2.

Table 1: Composition Percentage for Titanium Alloy

Composition	Percentage
H	0.005
N	0.01
C	0.05
Fe	0.09
V	4.4
Al	6.15
Ti	89.295

Table 2: Material Property of Titanium Alloy

Property	Value at Room Temperature
Density	4.512 g/cc
Tensile strength	993 MPa
Yield Strength	830 MPa
Modulus of Elasticity	113 GPa
Poison’s Ratio	0.37
Shear Modulus	45 GPa
Hardness, Rockwell C	36

FINITE ELEMENT APPROACH OF MILLING CUTTER

The CAD model of the cutter is developed using Autodesk inventor application software and its axis is aligned with a rectangular block type work piece as shown in Figure 1. The imported CAD model is used for transient structural analysis in ANSYS workbench with an objective of determining the dynamic response of a structure under the action of any time-dependent loads. The model provided with coordinate systems, material properties, analysis setup for part

geometry, reference temperature, rotational velocity and velocity for the work piece. The model is meshed using tetra mesh as shown in Figure2. In order to attain the smoother distribution of contact stresses the simulation is carried out with higher mesh density on contact surfaces.

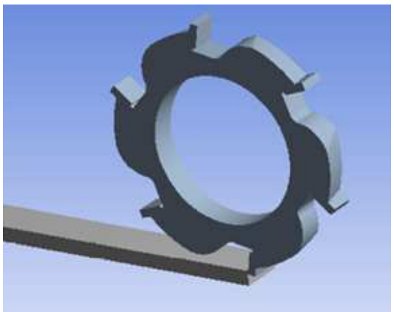

Figure 1: Model of Milling

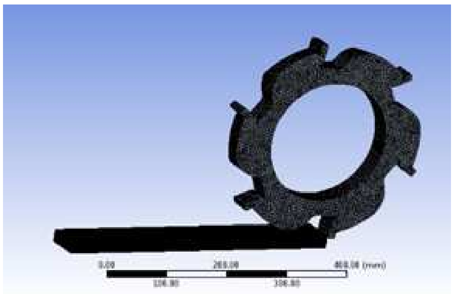

Figure 2: FE Model with Boundary

Cutter with Work Piece Conditions

The time step size is controlled using step controls in a transient analysis. These are utilized to perform two unique functions namely indicating analysis parameters set for each step and defining steps.

Table 3: Parameters Considered for FEA Analysis Setup

Step controls		**Non-linear controls**	
No of steps	1	Force convergence	Program controlled
Step end time	1s	Displacement convergence	Program controlled
Auto time stepping	on	Rotation convergence	Program controlled
Define by	Substeps	Line search	Program controlled
Initial substeps	1000000000		
Minimum substeps	1000000000		

Table 4: Parameters of Displacement, Velocity and Rotational Velocity

Steps	Time (s)	Displacement (m)	Velocity (m/s)	Rotational Velocity (rad/s)
1	0	0.001	0.008	75
1	1	0.001	0.008	75

RESULTS AND DISCUSSION OF THE SIMULATION

ANSYS workbench application software is used to perform static analysis of end milling cutter on work piece. Time period and stresses acting on the tool are the significant criteria during machining, which influences the tool life followed by the quality of the machined work piece. As these parameters are interrelated to each other, it is important to finish the milling operation within the time to optimize the stresses. During the analysis it is found that, stresses on the cutter increases with strain and as the stresses elevate, tool usage also higher. The analysis of optimally designed cutter has shown the improved tool life with lower stresses on it.

Table 5: Von-Mises/Equivalent Stress of Milling Cutter

Equivalent Shear Stress	162.63 MPa
Von Mises Stress	795 MPa
Equivalent Elastic Strain	1.09
Equivalent Plastic Strain	0.605
Life at failure region	~15000 cycles @0.019

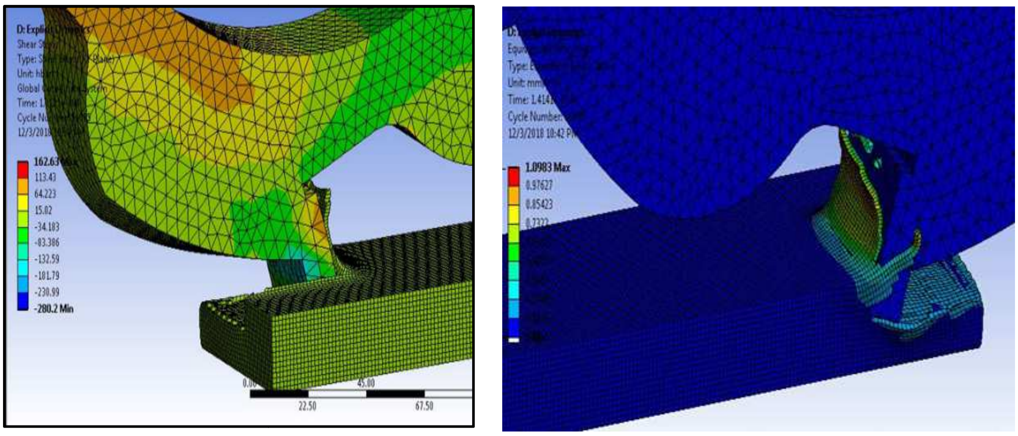

Figure 3: Von-Mises/Equivalent Stress (MPa)

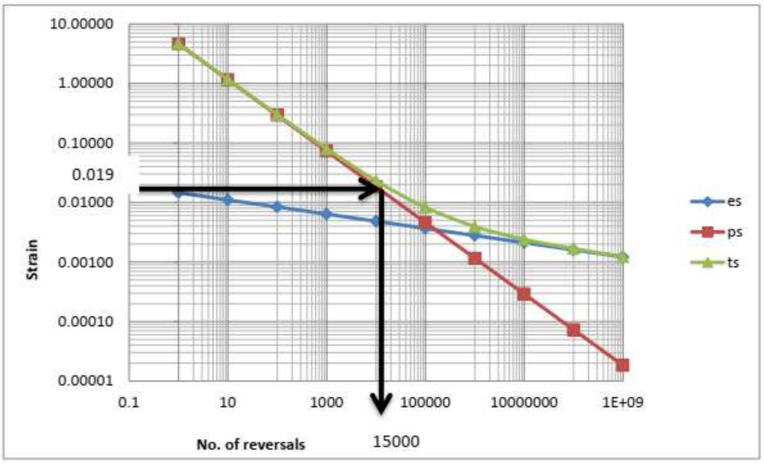

Figure 4: Universal Slope

CONCLUSIONS

In this investigation an optimal design of an end mill cutter and inserts were developed by using Autodesk Inventor software and ANSYS workbench is used for simulation. Based on the simulation results, stresses observed on the end mill insert and the work piece region are lesser which increases the life of the tool.

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